5-1-1978

A study of the effect of fabric structure and mesh count variation in indirect stencil preparation in a school graphic arts laboratory

James Tenorio

School of Printing
Rochester Institute of Technology
Rochester, New York

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

James K. Tenorio

with a major in Printing Education
has been approved by the Thesis Committee
as satisfactory for the thesis requirement for
the Master of Science degree at the convocation of

May, 1978

Thesis Committee: Robert Webster
Thesis Advisor

Julius Silver
Graduate Advisor

Mark Guldin
Director or Designate

A STUDY OF THE EFFECT OF FABRIC STRUCTURE AND MESH COUNT VARIATION IN INDIRECT STENCIL PREPARATION IN A SCHOOL GRAPHIC ARTS LABORATORY

by

James K. Tenorio

A thesis submitted in partial fulfillment
of the requirements for the degree of Master of Science
in the School of Printing
in the College of Graphic Arts and Photography
of the Rochester Institute of Technology

May, 1978

Thesis advisor: Professor Robert Webster

ACKNOWLEDGEMENTS

It would be very hard to individually list and thank all of the persons who have given me assistance in completing this thesis, from planning to analysis to typing. So one big word of thanks will be put on the record here for all, and I look forward to any chance of working with such fine people again in the future.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

A STUDY OF THE EFFECT OF FABRIC STRUCTURE AND MESH COUNT VARIATION IN INDIRECT STENCIL PREPARATION IN A SCHOOL GRAPHIC ARTS LABORATORY

by

James K. Tenorio

An Abstract

A thesis submitted in partial fulfillment
of the requirements for the degree of Master of Science
in the School of Printing
in the College of Graphic Arts and Photography
of the Rochester Institute of Technology

May, 1978

Thesis advisor: Professor Robert Webster

ABSTRACT

In order to choose the best working fabric for screen printing in a school graphic arts laboratory, a representative group of eight polyester fabric samples were tested. The fabrics covered a range of mesh counts from coarse to medium and included fabrics of both multifilament and monofilament types for each mesh count. Both types were of medium grade or quality, "XX" for the multifilament and "T" for the monofilament.

A specially designed resolution test object was printed by college level students in an introductory graphic arts class using indirect stencils with the sample fabrics. The stencil and five of the fifty copies from each student were inspected to obtain stencil edge definition and print resolution data. The subjects also completed a report sheet to provide information about stencil leakage, plugging problems in the mesh and stencil adhesion failures.

Resolution and edge definition data were each subjected to a two factor analysis of variance, the two factors being fabric type and mesh count. Information from the student reports was tallied and plotted in histogram form for comparison of the incidence of printing problems.

Results of the experiment showed a high degree of interaction between fabric type and mesh count, making it hard to generalize about effects of the two factors for finest resolution obtainable. Each combination of mesh count and fabric type had to then be compared to see exactly which samples would give specific results. Two fabric samples, 200 mesh and 25XX, gave finest resolution and two others, 135 mesh and 10XX, gave the lowest resolution. No effect was evident for edge definition. Student reports pointed out that the multifilament fabric was less prone to stencil adhesion failures and leakage problems.

A great deal of variation due to individual student differences was also found, and because of such wide dispersion, many of the fabrics produced results which were not found to be different, even though some of the meshes were on opposite ends of the range of samples. Another effect of the variation was the occurrence of trends which in a normal screen printing plant would not be expected to happen. Because of this, conclusions could only pertain to a school laboratory environment.

INTRODUCTION

The scope of this study was to determine the effect of different fabric structures and mesh counts on print quality (as measured by print resolution and stencil edge definition) ink flow and student results for screen printing in a school graphic arts laboratory. The aim of the study was to provide a quantitative basis on which to choose screen printing fabric that will perform well and be suitable for general use in a school lab.

To perform the experiment, eight different polyester fabrics were tested, four monofilament mesh counts and four equivalent multifilament mesh counts. Different sections of an introductory graphic arts class were given the different fabrics and all students printed the same kind of product. To measure the resolution of the print, a specially designed test object was included in the layout for each color of the job. Edge definition was microscopically measured on the stencil by counting the number of peaks or teeth per linear millimeter on the edge of the image. Results were subjected to an analysis of variance (ANOVA). Student stencil failures and ink flow data were reported by each student and the frequency of each were plotted for comparison between fabric samples. Conclusions were then drawn from the data.

Interest in this topic started when the author began teaching graphic arts. Screen printing was part of the curriculum, but quality and popularity of the process was lacking since the methods and materials used up until that time were rather poor. One type of fabric, one kind of ink, one size of squeegee and frame, all the cheapest available, led to many shortcomings, especially since screen printing is the most versatile medium in the graphic arts when used properly. When the author started to make revisions in the methods and materials, the hardest item to choose was the screen printing fabric. No information existed, as with ink and stencils for example, that gave a good recommendation as to which fabric would be best for student use. In order to make a qualified choice for future fabric purchases, it was decided to run an experiment to test the performance of different fabrics in an actual educational setting.

BASIS FOR THE STUDY

Screen printing is one of the fastest growing areas in the graphic arts industry. In the seventy year span of its commercial existence, it has emerged from a craft and art medium status to a highly sophisticated technical reproduction process. It now ranks fourth of the major graphic processes and is doing more and more of the work that used to be done by letterpress, lithography, gravure and other processes.[1] Since 1970, the growth rate of screen printing has been between 17 and 20 percent annually. These figures, obtained from members of the Screen Printing Association International, are even believed to be low, since there are many small basement and back room shops which are not members of the association and are hard to find. Membership in the organization itself is now at an all time high. Presently, 1200 members participate in the association. As is characteristic of the rest of the printing industry, when the amount of work produced by these many small shops is added together, the total is impressive -- more than five billion dollars in net sales annually.[2]

A major factor which makes screen printing such a successful and steadily growing process is its versatility.

Screen printers claim to be able to print on just about anything. This versatility stems from the design of the process itself (Figure 1).

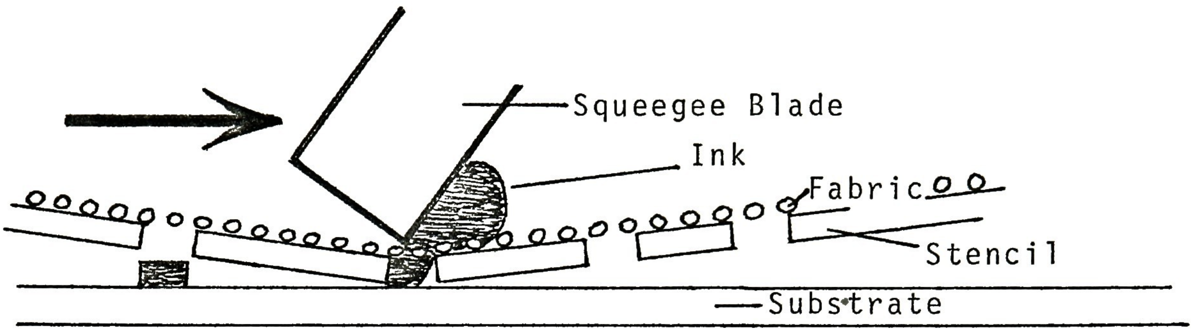


FIGURE 1

Screen Printing

Porous fabric is tightly stretched and adhered to a rigid frame. An image is produced on a stencil. The stencil has openings in the shape of the desired image which will later allow ink to pass through. The non-image areas are the stencil material itself, and these prevent ink from passing through to the substrate. The stencil is prepared and adhered to the stretched fabric in any of a number of ways depending upon the kind of stencil being used. Any open areas of the fabric around the stencil are then blocked out to prevent ink passage. Ink is put into the frame and the substrate is positioned beneath the frame. A rubber blade called a squeegee is then scraped against the fabric forcing the ink to pass through the open areas of the stencil and fabric and onto the substrate. With this arrangement, a film of ink much thicker than any of the other reproduction processes can be laid on nearly any kind of surface. Applications which even some people in the graphic arts don't consider to be in their field make use of this thick film advantage. Varnishes, resists, conductive and insulative coatings for many different products are often screen printed. Inks and coatings can be made to successfully print and adhere to specific materials. Very large image areas are also easily printed. In addition to flat materials of all kinds, screen printers can easily print on three dimensional objects of nearly any shape -- cylindrical, cubical, even conical shaped, just by changing the shape of the frame and the design of the screen printing press. Very little pressure is needed to force the ink through the screen, so for very fragile objects, screen printing is a natural first choice.[3]

With all of these advantages, it is easily seen why screen printing has been gaining popularity as a reproduction process. In keeping with this trend, more and more schools, both secondary and post-secondary are beginning to teach screen printing as part of a graphic arts curriculum. In all of the programs the author has seen or visited, screen printing has proven to be an area of great student interest. The simplicity of the process makes it easy for most students to master the concepts. The versatility allows them to apply what they have learned to many different kinds of class and personal projects.

A problem in the school laboratory situation has arisen, however, due to a number of reasons. The problem is that many instructors are teaching screen printing on a trial and error basis. This fact was discovered while the author was visiting various secondary schools to gain background information for an industrial education conference presentation. Most of the instructors interviewed were not aware of materials and techniques available which are common knowledge in the screen printing industry. This lack of applicable technical information was the main reason why programs are run this way. When the author's presentation was given at the conference, the most prevalent question asked was, "Where can I get information on materials and supplies?" Secondly, to further complicate things, when information is finally found, it is usually discovered (for screen printing) that it is not always applicable to a school situation since it was prepared for intended use by commercial and industrial screen printers. A school laboratory environment is not the same as is found in industry. In schools there is a definite lack of control over variables which are important to consistent screen printing. The biggest variable is human. Each student will try to do a process or procedure a little differently from the next. In industry, one person on the job will perform the same task in nearly the same way every time since he has had time to become practiced at it. Other variables such as environmental control in a shop are less likely to be fixed in a school laboratory, especially if the facility is an older one. Information given to screen printers often refers to use of modern equipment which lessens the chance of variability. Fabric stretchers and ink drying equipment are examples of this. Sophisticated equipment is expensive, and at the present time, many schools are operating under limited budgets. It can thus be seen that there is a definite need for available information that is applicable to the special situation of a school graphic arts laboratory.

Obtaining the proper materials and equipment is a first step in having success with students in a graphic arts program. While making mistakes and solving problems is agreed to be one of the best ways to learn a process, the problem should not be caused by something the student has no control over: the type of equipment or materials supplied to him. Enough mistakes are usually made without this extra complication. Successful ventures in screen printing will not only generate enthusiasm for the process itself, but also will spark interest in the other graphic arts processes as well.

A listing of the basic materials needed to do screen printing follows:[4]

The stencil:

Stencils can be of two major types, hand made and photographic. Hand made stencils are easy to produce and require a minimum of equipment and expense. Stencils can be cut from heavy paper or from commercially available films. In both kinds, the principle is the same. All of the areas that are to be printed are cut away using some kind of sharp tool. Commercial films are adhered to the fabric according to manufacturers instructions and paper stencils are positioned by simply taping them to the underside of the fabric on the printing frame. Photographic stencils are divided into two main categories, direct and indirect. The main advantages of a photographic stencil are twofold. First, it has the ability to reproduce finer detail than is possible with a hand made one. Second, a number of identical stencils can be made of equal quality since the repeatability of the process does not depend upon a person's manual dexterity during imaging of the stencil material. In a direct emulsion stencil, a light sensitive liquid coating is put onto the fabric which has been stretched onto a frame. After it dries, the whole frame is exposed by bright light through a film positive. The areas that are light-struck are hardened. The entire frame is then washed in warm water, dissolving away the unexposed areas which will become the image. The problem in employing this method in a school is that a special exposure device is needed to accommodate the frame. Transfer film stencils, another type of direct stencil, use both a liquid light sensitive coating and a piece of film. The two are applied to the fabric with the liquid also acting as an adhesive to hold the film in place on the underside of the fabric. Like a direct emulsion stencil, the whole frame is put into an exposure unit and then processed. Negative reverse stencils, the last of the direct stencils, are used primarily for extremely long runs since the principle involves using an epoxy coating for the stencil material. First a stencil is made by the direct method which has the image areas blocked out instead of the non-image areas. Exposure is made through a negative rather than a film positive. The epoxy is then coated on the fabric filling in the open non-image areas. After final curing of the epoxy, the image areas are washed away leaving the epoxy stencil in the fabric. Indirect stencils are also light sensitive, but here, the material is a piece of film which is exposed with a film positive, processed and then adhered to the fabric. In schools where lithography is taught, indirect stencils are easy to incorporate if offset platemaking facilities exist.

The most popular stencils for school application are the hand cut films and the photographic indirect methods since each can be easily prepared using existing facilities.

The frame:

The materials for frames are wood, metal and plastics. The first two kinds can be easily home made, especially in a school where shop facilities may also exist for wood and metalworking. Frames must be rigid enough to resist bending and twisting, resistant to any water or solvent it may come in contact with, and light enough to permit easy handling. Frames can be bought which will also stretch and hold the fabric in place by themselves. These self-stretching metal frames are rather expensive when rigid frames are so easily made in-plant. Fabric is attached with an epoxy adhesive to metal and plastic frames and can be held by adhesives, stapling or with a cord and groove to keep the fabric in place on wooden frames. Mechanical or pneumatic stretching devices are necessary if the adhesive method is to be used. Many schools use wooden frames with staples or the cord and groove method to hold the fabric.

The squeegee:

Squeegees are commercially available from screen printing suppliers and can be made in any length desired. The resillient blade varies in composition and shape. Durometer or hardness of the blade varies with composition and the shape depends on the nature of the material to be printed upon. Flat surfaces and textiles are the most common materials used as substrates in a school laboratory, and the recommended shapes here for squeegees are square edged and rounded blades, respectively (Figure 2).

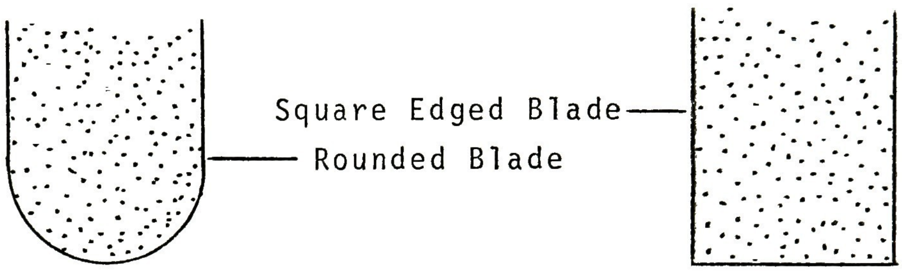


FIGURE 2

Squeegee Blades (Cross Section)

Inks:

Many different inks are available and the choice of an ink depends greatly upon the substrate and the end use of the product. Ink manufacturers spend a great deal of effort developing and testing inks for specific uses and materials. Suppliers publish catalogues and lists detailing this information. Cost of the inks is an important consideration for a school laboratory, so a careful evaluation of the kinds of anticipated jobs to be run should be made before inks are ordered. Another consideration relating to ink choice for a school is the ink solvent needed for washup and cleaning. A great variety of inks which require the use of many different solvents would be very expensive.

Fabrics:

The choice of a screen printing fabric is probably the most difficult of the five factors involved in screen printing. It is the one which causes the most controversy among printers. The fabric has the important functions of supporting the stencil and allowing ink to pass through wherever the stencil is open. Commonly available fabric materials are silk, organdy, nylon, polyester, stainless steel, and metal clad polyester. Fabric manufacturers have done a great deal of research and testing of fabric materials and give recommendations in their technical publications. These are a good starting point for choosing a fabric in a school laboratory, but because of the nature of the manufacturer's testing, and the many variables and problems associated with a school laboratory mentioned earlier, the final choice of an ideal supply of fabric rests on the experience of the instructor. Researchers conduct tests using controlled stretching and mounting procedures with the most up to date machinery. An example of this is a device which when laid on the taut fabric, can give a numerical reading corresponding to the degree of stretch in the fabric. Fabric manufacturers, aware of the great variety of inks and substrates screen printers encounter, take this into account when recommending fabric applications to users.

The testing of stencil performance of fabrics is carefully controlled using consistent exposure and processing techniques. Experienced people conduct the tests and recommendations are given. Recommendations for fabric choice, based on manufacturers' suggestions but tested in actual school laboratory conditions, are badly needed.

This study attempts to discover which types of screen printing fabrics perform best in an actual school graphic arts class situation. Different fabrics are tested and results are evaluated by comparing print quality and the success rate of students in preparing the stencils. Print quality is defined by measuring print resolution, stencil edge definition and incidence of sawtoothing in the fabric mesh. Student success is measured by comparing the frequency of stencil adhesion failures, stencil breakdowns or leakage, and plugging problems in the fabric mesh among the different types of fabrics tested.

FOOTNOTES FOR CHAPTER 2

1. Kyle, E.J., "Split Personality," Screen Printing (June, 1977), p. 50.

2. Shaw, John S., "Screen Printing . . . Today and Tomorrow," Graphic Arts Monthly (October, 1973), p. 88.

3. Advance Process Supply Corporation, "It's a Screen Printed World," Film, 1969.

4. Rochester Institute of Technology, Screen Printing, Course of Study (Rochester, NY, Rochester Institute of Technology, June, 1976), class notes of James K. Tenorio.

DEFINITION OF TERMS

The following are terms which are used throughout the study.

Blockout - To obstruct open non-image areas of a screen or stencil so ink will not penetrate.

Edge Definition - The ability of the stencil material to reproduce images of the same resolution as is on the original film positive. This can be measured by the incidence of tiny points, or sawtoothing, in number per linear measure seen on the stencil along the edge of an image.

Fabric - Porous cloth stretched on a screen printing frame. Its function is to hold the stencil in place and allow ink to pass through the open areas in the mesh.

Multifilament - A fabric type whose threads are made up of many separate strands. (Figure 3.)

FIGURE 3

Cross Sections of Thread

Monofilament - A fabric type whose threads are each made up of one continuous strand. (Figure 3.)

Mesh Count - A system of defining how finely a fabric has been woven. The mesh count of a fabric is measured by the number of openings between the threads per linear inch or linear centimeter. Multifilament fabrics have mesh count designated by a graded number ranging from 2XX to 30XX (coarsest to finest respectively). The X's after a mesh number refer to what is called "quality" of the fabric. More X's mean higher "quality" which is actually a thicker thread in the mesh. Monofilament fabrics are designated by the actual mesh count, usually anywhere from 30 to 500 openings per linear inch. "Quality" of monofilament fabrics can be of three classes, "S" or fine, "T" or medium and "HD" or heavy. Again, the change is in the thickness or diameter of the thread which affects the percentage of open area in the mesh.

Frame - The rigid box-like apparatus which holds the fabric in place.

Ink - Pigmented liquid which is applied to the substrate, mentioned here because of the fact that people still sometimes erroneously refer to the ink as "paint".

Pinhole - Tiny opening in the stencil in non-image areas which are undesirable on the print.

Plugging - The drying of ink between the threads of the fabric in image areas, thus obstructing the flow of ink.

Resolution - A measure of print quality described as the number of parallel lines that can be printed within a certain lineal distance (inches or centimeters) clearly.

Resolution Test Object - An image consisting of very fine detail designed to measure the number of parallel lines that can be printed clearly within a certain lineal distance.

Sawtoothing - The tendency of a screen printing stencil to follow the pattern of the fabric along the edge of an image. Appears as a regular pattern. Particularly a problem with direct stencils.

Stencil - The image carrier of screen printing. Contains unobstructed areas in the shape of the desired image and restricts the flow of ink in the non-image areas.

Squeegee - A resillient blade, either rubber or synthetic material, which forces ink through the open areas of the fabric and stencil.

Substrate - Any material to be printed upon by a reproduction process.

RELATED RESEARCH

When compared to the amount of research being conducted by individuals and groups in the other major reproduction processes, the amount done in screen printing seems almost non-existent. One possible reason may be the fact that commercially, screen printing has only been around for seventy years, compared with letterpress or lithography which have commercial histories dating back hundreds of years. Another reason is the outdated attitude many people in the graphic arts still have toward the process. It is often regarded as just an arts and crafts medium, with no potential for sophistication.[5] Foremost in the field of research in screen printing are the fabric manufacturers. They produce and publish manuals outlining the use of their screen material. Recommendations for specific uses are given and guidelines can be confidently followed if the screen printer is careful to control variables and follow exact procedures for stretching and adhering fabrics, producing stencils, and printing. It has already been mentioned how a school laboratory is a far cry from such controlled conditions. The manufacturers who are active in this research are the Zurich Bolting Cloth Manufacturing Company, the Swiss Silk Bolting Cloth Manufacturing Company and the Saati Group, an Italian organization. In the United States, some of this information is distributed by the TETKO Corporation[6] and another manufacturer, the Majestic Bolting Cloth Corporation, both of New York.[7] Other major fabric manufacturers and distributors are the Advance Corporation of Chicago, Industrial Fabrics Corporation, Minneapolis, and Gerard Daniels Company of New Rochelle, New York.

Research by individuals begins with a study conducted by E. J. Kyle and reported in several issues of Screen Printing magazine between November, 1970 and June, 1971. His study is one of determining a way to measure very fine resolution, approaching a thousandth of an inch and was entitled, "Toward the One-Mil Line."[8] He uses transfer film stencils and a resolution test object that would account for direction of the fabric weave (Appendix A). While the present study does not use transfer film stencils or print lines as fine as one mil, it uses a similar test object as a means of determining resolution both on the print and the stencil.

More research on screen printing stencils was conducted by George Bedirian in May, 1977. His study is concerned with direct stencil edge definition as a result of changes in coating techniques and fabric variation. The study is an interesting one and pointed out that under certain instances, good edge definition is obtainable with only a single coating of emulsion, even on coarse fabrics.[9] The problem in relating this study to the present one is the fact that Bedirian uses direct stencils while indirect ones are incorporated here. It did, however, make the author aware of Kyle's test object for use in this study.

Another very interesting study, conducted in 1970 by Thomas R. Bresadola, tests humidity effects among different types of stencils. It proves that the least affected by humidity increases was the direct stencil with the photographic indirect and hand cut indirect stencils following in that order.[10] Humidity is not a factor in the present experiment, but the results of his work would be of great interest to those screen printers who may be considering environmental control for their plants.

A final detailed study entitled Screen Printing Considerations for Thick Film Microelectronics compares the variables of stencils, fabrics and printing techniques for printed circuitry. Conducted in 1973 by Lynn Fuller, the study would be of value to a printer about to enter the field of screen printed electronics, but for a study concerned with the much less exacting problems of a school laboratory, nothing more about Fuller's study need be said.[11]

Lastly, the author of this present study has done some very informal sampling of different screen printing fabrics among his classes at the University of Wisconsin-Stout.

Different types of fabrics were placed on frames, and performance, primarily in the realm of screen reclaimability, was observed by occasionally checking the fabrics by visual inspection. No records, however, were kept, nor were any results obtained.

From the amount of presently available information seen, it is obvious that more research is needed in the area of fabric performance under the particular conditions of a school laboratory.

FOOTNOTES FOR CHAPTER 4

5. Kyle, p. 50.

6. Zurich Bolting Cloth Mfg. Co. Ltd., _Manual for the Use of NITEX Monofilament Screen Fabrics for the Graphic Arts Industry_ (Zurich: The Zurich Bolting Cloth Mfg. Co. Ltd.), p. 7.

7. Majestic Bolting Cloth Corp. "About Fabrics," (New York: The Majestic Bolting Cloth Corp.)

8. Kyle, E.J., "Toward the One-Mil Line," _Screen Printing_ (November, 1970 to June, 1971).

9. Bedirian, George, _A Study of the Effect On Direct Stencil Edge Definition of Emulsion Thickness, Screen Mesh Count, Fabric Thread Thickness and Coater Blade Thickness_ (Rochester, NY: The Rochester Institute of Technology, May, 1977) p. 39.

10. Bresadola, Thomas R., _An Experiment on the Effects of Humidity on Screen-Process Stencils_ (South Dakota State University, 1970), p. 26.

11. Fuller, Lynn, _Screen Printing Considerations for Thick Film Microelectronics_ (Rochester, NY: The Rochester Institute of Technology, June, 1973).

METHODOLOGY

The experiment was conducted as follows. Four sections of the introductory graphic arts course at the University of Wisconsin-Stout were used as subjects. The course title and number was Graphic Arts 130-140.

Before the actual data for this test were collected, a pilot study was made using one class section. The entire experiment, aside from analyzing data, was conducted in order to find the best way to handle the number of people and all of the variables involved in the experiment. From this, the final plan for administering the design was drawn.

Each student of each section received two pieces of polyester fabric of different mesh counts and/or types for completing their screen printing assignment as part of the course. The fabric samples were 100, 135, 175 and 200 mesh monofilament of grade "T", and 10XX, 14XX, 18XX and 25XX multifilament. This covered the range of readily available and commonly used coarse to medium meshed fabrics. Similar mesh counts for the two types of fabrics were chosen for comparison, and the mesh groups appear in Table 1.

TABLE 1

Polyester Fabrics Tested

Multifilament	Monofilament
Equivalent Mesh Counts	
10XX	100
14XX	135
18XX	175
25XX	200

Had more sections been available, more and finer fabrics could have been included. The monofilament fabric was dyed orange or yellow, while the multifilament fabric was white. Color of fabric only makes a difference when direct stencils are used, so here with indirect stencils, the colors were used for identification purposes. Mesh count of the fabric was marked in the corner of each piece with the appropriate mesh number.

All sections used frames of the same size. Nearly 100 frames were made measuring 35X50 cm which would accommodate standard size sheets of stock (8-1/2" x 11"). Fabric was hand stretched and mounted to the frames by the cord and groove method, which is common in school labs. Before adhering stencils to monofilament fabric, the mesh was treated by roughening with 500 mesh silicone carbide abrasive. This increased surface area of the threads so the stencil could adhere better. All fabrics were then thoroughly degreased with a three percent solution of tri-sodium phosphate and then rinsed clean. Students prepared film positives for stencil exposure by exposing a piece of Kodak "Kodalith Type 3" ortho film on a Kenro vertical process camera to their original copy. The resulting line negative was then contacted onto a second piece of ortho film to obtain a film positive. All students followed posted exposure and processing times so film positives were of the same densities throughout the classes.

In order to accurately measure print resolution and have a consistent measurement device for stencil edge definition, a test object was designed and identical film positives of it were prepared for the classes to use. The positives had the object positioned in different places so the target could be easily fit as needed into the design of the student's assignment. Some students even incorporated the shape of the object as part of the design itself. A sample of the pattern was provided to help in the designing of the project along with instructions for completing each step. (Appendix B).

The object (Figure 4) consisted of a series of seven equally sized and spaced lines in seven groups or zones which decreased in size and all radiated at 15^0 intervals from a center point. The zones covered a 90^0 arc in order to allow for the direction of the fabric weave. The zones decreased in size by a factor of the square root of two so

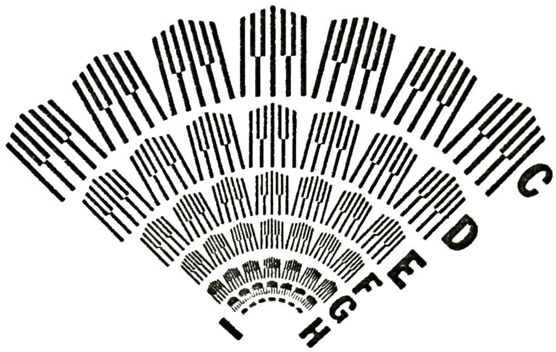


FIGURE 4

Resolution Test Object.

that for every other step, up or down in size, the resolution was either doubled or halved, respectively. The resolution in lines per centimeter for each zone appears in Table 2.

TABLE 2

Resolution for Zones of Test Object

Zone	Resolution
C	7
D	10
E	14
F	20
G	28
H	40
I	56

The original for the test object was prepared using hand cut masking film with each line measuring .5 cm wide.

All further reduction work to make a paste-up was done on the process camera using diffusion transfer materials to keep the image in negative form. This avoided degrading the image due to flare caused by a surrounding bright field. A master negative was then made of the paste-up using Kodak "High Speed Duplicating Film". The positives used by the subjects were at last made by contacting the master negative onto "Kodalith" ortho film measuring 10 x 12 inches. All positives were measured to insure that they were accurate.

A photographic indirect stencil was used for the experiment; made by Ulano Corporation, it was their "Blue Poly 2" brand of stencil. Stencils were exposed through the base using both the student prepared and the provided film positives sandwiched together. The provided positive containing the test object was placed nearest the stencil. The materials were loaded into a vacuum frame and exposed with a 250 watt mercury vapor lamp for 70 seconds from a distance of 22 cm. Processing of the stencil was done according to manufacturers instructions. First the stencil was developed in Ulano "Hi-Fi" developer for 90 seconds at a temperature not over $24^{o}C$ ($75^{o}F$) with constant agitation. Then the image areas were washed out with gently running water held between 35 - $38^{o}C$ (95 - $100^{o}F$) until clear. The processed stencil was then mounted onto the bottom or job side of the just-degreased screen, and all excess water was blotted out by applying unprinted newsprint to the top or inside of the screen. Hand rolling, without applying any extra pressure, a 1.5 kg brayer to the newsprint helped to remove the moisture. Stencils were allowed to completely dry without any heat or forced air and then the open mesh surrounding the stencil was masked using two thin coats of liquid block-out and gummed kraft tape. Before printing, the 50 sheets of 80 pound "Sundial Vellum" cover paper were numbered and marked with a diagonal line along the edge of the stack (Figure 5).

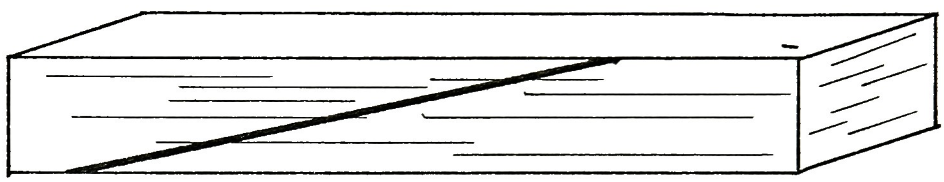


FIGURE 5

Marking the Stack of Printing Stock

The screen printing ink used was Advance Corporation's "SAM" series production poster ink. The different colors were each mixed one part clear base to three parts ink. One half ounce of Advance "T-950" retarder was also added to each quart of the ink mixed. Ink was put into the frame, image registered and the 50 copies were printed in consecutive order. Three additional sheets were also printed for the student's use as part of the original class assignment. After cleaning out the ink, the frame was turned in to the instructor. A project report sheet (Appendix C) was completed before the final work was submitted which provided more information for fabric evaluation. Some samples of student work can be found in Appendix D of this study.

Data were collected as follows. Edge definition of the stencil was checked before and after printing with a 40 power recticuled microscope. The average number of "peaks" or "teeth" per millimeter was determined by inspecting three groups of zone "C" in the test object, two on each end of the arc and the group in the center. The change in number of peaks per mm before and after printing was used as data in the analysis of variance for the edge definition.

Resolution on the print was checked by inspecting copies numbered 10, 20, 30, 40 and 50 of the printing run. The letter of the finest resolved zone to be printed without image loss or lines blending together was recorded for each of the five sheets. From that, the average (mean) resolution was determined for each student. The net change in resolution was also found by comparing the resolution of copies 10 and 50. An analysis of variance was done for both effects.

Student results or "success" was noted by the number of remakes due to stencil adhesion failure that were needed. The percentage of students per fabric mesh count who reported the problem was computed. Number and percentage of leaks in the stencil were also noted during the printing run as another indication of stencil failure. Ink flow characteristics were found by again figuring the number and percentage of students in each group who reported problems with open areas of the screen mesh plugging up with ink during printing.

HYPOTHESES

It is hypothesized that different degrees of resolution, edge definition and student results will come from different levels of each of the variables of fabric type and mesh count. Stated in null hypothesis form, the hypotheses are as follows:

1) There will be no difference in print resolution for indirect stencils adhered to multifilament and monofilament fabrics.

2) There will be no difference in print resolution for indirect stencils adhered to the different mesh counted fabrics.

3) There will be no difference in stencil edge definition for indirect stencils adhered to multifilament and monofilament fabrics.

4) There will be no difference in stencil edge definition for indirect stencils adhered to the different mesh counted fabrics.

5) There will be no difference in student results for indirect stencils adhered to multifilament and monofilament fabrics.

6) There will be no difference in student results for indirect stencils adhered to the different mesh counted fabrics.

DATA COLLECTED FOR EXPERIMENT

TABLE 3

DATA COLLECTED FOR 10XX FABRIC

SEMESTER II SECTION 9

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	1	23.6	- 8	-	-	-
2	0	14	0	5	1	-
3	1	28	0	-	-	-
4		10.2	3	1	1	-
5	2	35.2	0	-	3	-
6	1	28	0	1	-	-
7	0	28	0	-	2	-
8		25.2	-14	-	-	-
9	3	17.6	0	-	1	-
10	2	24.8	- 8	-	-	-
11	0			1	-	-
12	3	21.6	0	-	-	-
13	3	20	0	-	-	-
14	0	28	0	-	-	-
15	0	24.8	8	-	-	-
16	0	14	10	-	-	-
17	1	15.4	- 3	-	-	-
18	3	28	0	1	-	-
19	0	19.2	0	-	-	-

TABLE 4

DATA COLLECTED FOR 100 MESH FABRIC

SEMESTER II SECTION 8

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	3	14.4	-10	-	-	-
2	3	24.8	8	-	-	-
3		13.2	0	-	-	-
4		15.2	- 6	-	-	-
5	1	14	0	-	-	-
6		10	0	-	-	-
7		16.4	- 6	-	-	-
8	0	20	0	-	2	X
9	0	24.8	18	-	-	X
10	2	20	0	-	-	-
11		14	0	-	-	-
12		14	0	-	-	-
13		29.2	30	1	2	X
14		20	0	-	-	-
15		24.8	- 8	-	-	-
16	2	24	30	1	3	-
17		30.4	0	-	10	-
18	3					-
19		20	-	-	-	-
20	0	20.4	-14	-	-	X
21	0	30.4	12	-	-	-

TABLE 5

DATA COLLECTED FOR 14XX FABRIC

SEMESTER 1 SECTION 2

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	6	37.6	0	-	1	-
2	4	10	0	-	-	-
3	4	14.4	0	-	-	-
4	3	28	0	-	-	-
5	3	10.8	4	-	2	-
6	2	28	0	1	4	-
7						
8	2	17	33	-	-	-
9		28	0	-	-	-
10	0	34.8	0	-	-	-
11		16.8	0	-	-	-
12		23.6	8	-	-	-
13		24.8	-14	-	-	-
14						
15	1	32.8	0	-	-	-
16		24.8	8	1	-	-
17	0	23.2	8	-	1	-
18	0	29.2	14	1	-	-
19		20	0	-	1	X
20	0	33.6	12	-	1	-
21		40	0	-	-	-
22	2	28	0	-	1	-
23	3	28	0	-	1	-

TABLE 6

DATA COLLECTED FOR 135 MESH FABRIC

SEMESTER II SECTION 2

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	2	15.2	- 6	-	-	X
2		24.8	8	1	3	X
3		9	7	-	3	-
4		16.4	6	-	1	-
5		14	0	-	-	X
6		14.4	10	-	-	-
7	1	14	0	-	-	-
8		28	0	3	1	X
9	2	13.6	0	-	-	-
10	1	14	0	-	-	-
11		28	0	-	1	-
12		26.4	0	-	-	-
13		20	0	2	-	-
14	1	7	0	-	2	-
15	3	17.6	- 6	1	3	-
16	3	22.4	-14	1	-	-
17	0	20.4	14	-	-	-
18	0	14.8	0	-	-	X
19	4	14	0	-	-	-
20	3	16.4	- 6	-	2	-

TABLE 7

DATA COLLECTED FOR 18XX FABRIC

SEMESTER II SECTION 7

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	4	26.4	0	-	-	-
2	2	24.8	- 8	1	2	X
3	2	25.2	0	-	-	-
4	0	10	0	-	-	-
5		33.6	12	-	-	-
6	0	17.6	- 6	-	-	-
7	0	28	0	-	-	X
8		20	0	-	-	X
9	5	29.6	-20	-	-	X
10	4	23.2	- 8	1	2	-
11	0	28	0	-	-	X
12	4	26.4	0	1	-	-
13	0	20	0	-	-	-
14	5	10.2	4	-	-	-
15	4	28	0	-	-	-
16	2	28	0	-	-	-
17		21.6	0	1	3	X
18	1	28	0	-	-	-
19	2	21.6	0	-	-	X

TABLE 8

DATA COLLECTED FOR 175 MESH FABRIC

SEMESTER II SECTION 9

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	3	20	0	-	-	-
2	1	20	0	4	1	-
3	3	28.8	- 8	-	-	X
4	2	14	3	-	1	-
5	3	28	0	1	-	-
6	2	35.2	0	1	1	-
7	4	37.6	0	2	2	-
8	4	22	- 8	2	1	X
9	3	22	-14	-	2	-
10	0	26.4	8	-		-
11				1	1	-
12	1	28	0	-	-	-
13	4	20.8	-14	-	-	-
14	2	20.4	- 8	-	-	-
15	0	30.4	12	-	1	-
16	4	15.2	0	-	1	X
17	4	20	0	-	1	-
18		28	0	2	-	-
19	4	23.2			-	-

TABLE 9

DATA COLLECTED FOR 25XX FABRIC

SEMESTER I SECTION 7

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1		23.6	0	-	-	-
2	3	25.2	0	-	-	-
3	1	36	0	-		-
4	5	20.4	6	-	-	-
5	5	29.6	12	-	-	-
6	4	28	0	-	-	-
7		35.2	12	-	1	-
8	0	30.4	0	-	-	-
9	5	32.8	12	-	2	-
10	0	20	0	-	-	X
11	2	36	0	-	2	-
12	0	28	0	2	2	-
13	5	25.6	0	-	1	-
14	3					
15	4	28	0	-	-	-
16	2	28	0	-	-	-
17	0	14	0	-	-	-
18	0	20.4	-26	3	2	-
19	4	22	14	-	-	-

TABLE 10

DATA COLLECTED FOR 200 MESH FABRIC

SEMESTER II SECTION 8

#	Change in Edge Defin. (Peaks/mm)	Mean Resolution (Lines/cm)	Change in Resolution (Lines/cm)	Stencil Adhesion Failures	Number of Leaks	Had Plugging Problems
1	0	13.2	- 4	1	-	-
2	5	17	-13	-	1	-
3		14.8	- 4	-	1	-
4		20	0	-	1	-
5	0	28	0	-	-	-
6	0	28	0	-	-	-
7		24.8	8	-	1	-
8	5	14	0	-	1	-
9	0	20	0	-	-	-
10		10	0	1	1	-
11	1	22.8	8	-	-	-
12		20	0	-	-	-
13	1	20	0	-	-	-
14	4	23.6	6	-	-	-
15	3	28	0	-	1	-
16		28	0	1	2	-
17	4	28	0	-	8	-
18		30.4	12	-	-	-
19		20	-	-	-	-
20		21.2	0	-	-	-
21	1	28	0	-	-	-

RESULTS OF THE RESEARCH

Results provided by the data showed little if any set pattern in many cases. In the area of print quality, data from the analyses of variance failed to show an effect of mesh or fabric variation for stencil edge definition, Table 13, or change in print resolution, Table 12. For average print resolution, the ANOVA supported the presence of an effect caused by the fabric structure (multifilament or monofilament). The probability given by the ANOVA was .00092 at the .01 level, which was very significant. By simply looking at the total mean resolutions of the two types of fabric, one can easily see that the multifilament produced the finer resolution, 24.63 lines/cm, compared with 20.89 lines/cm for the monofilament.

While the ANOVA failed to show any significant effect of mesh count alone, the probability was such that it came very close to being significant, .056 at the .05 level. An informal check of the means in Figure 13 for the mesh groups did point to a finer resolution for the two higher mesh groups, 24 lines/cm, than the lower two, 21.20 and 21.54 lines/cm.

Another more important result of the analysis, however, was the presence of interaction between the mesh number and fabric type factors. The significant probability here was .029 at the .05 level. Since this meant that the results of one factor would not be consistent across the levels of the other, a Newman-Keuls range test was performed for the mean resolution of each combination of fabric type and mesh. The eight means were compared as shown in Table 18 and the results shown in Table 19 point out that most of the fabrics could not be shown to be different from each other. The one which did prove to be different from most of the others was the 135 mesh monofilament. It was significantly different from the 14XX, 18XX, 25XX multifilament and 175 mesh monofilament at the .05 level and produced the lowest resolution, 17.52 lines/cm. The 100 mesh was also shown to be different from the 25XX fabric. Therefore, in regards to print quality, mean print resolution was the only criteria that was affected by the treatments. Also, no single factor was responsible for the effects taking place. This interaction of the two factors was shown in the ANOVA table (Table 11) and could also be seen by simply looking at the ranking of fabrics by mean resolution in the Newman-Keuls range test. Slight indication of trends in mesh counts is present, but since both are working in combination with each other, careful inspection of both are necessary before making conclusions.

The results for student success in using the different fabrics showed the monofilament fabrics were just slightly ahead of the multifilament ones in incidence of plugging problems, leakage, and stencil breakdown. By looking at Figures 7, 9, and 11 one can see that there were more reported incidences and a higher percentage of people in the classes reporting such problems in each of the three areas. The problem most clearly explained by the graphs is that of leakage through the stencil (Figure 6) during printing. Monofilament leakage occurred between 2 and 39% more often than on multifilament for each mesh count pair. The total number of stencil adhesion failures was also higher for the monofilament, but here in two of the mesh groups the multifilament did outnumber the monofilament. Plugging problems during printing increased as the mesh count of the fabric increased (Figure 10). At the highest fabric number, however, the number of reported problems dropped to almost zero. It could be assumed that in reporting the problems, this particular group did not give as detailed information as the others, since a definite trend was forming. Monofilament again had the highest incidence for total number of reported plugging problems (Figure 11). The same drop in a trend was also noted for the incidence of stencil adhesion failures (Figure 8).

ANALYSIS OF DATA

The results in Tables 3 through 10 were subjected to an analysis of variance (ANOVA) so that inference could be made concerning print quality. The criteria used to measure quality were mean print resolution of each printing run, change in print resolution, and change in stencil edge definition from the beginning to the end of each run. For the resolution analyses 5 copies of each student's run were sampled. These were the prints numbered 10, 20, 30, 40, and 50. If there were less than 45 copies submitted, 5 copies being evenly distributed throughout the run were chosen. Copy number 10 and copy 50 were used for the change in resolution data. Obtained was the resolution, in lines per centimeter, of the finest zone that was clearly reproduced on the sheet. At least 90% of the objects in the zone had to be free from image loss (lines missing) or gain (lines bleeding together) in order to be considered clearly reproduced.

The mean finest resolution was used for the ANOVA. Table 11 contains the results of the mean resolution ANOVA. Data for all ANOVA's were laid out as follows:

Fabric types		Mesh Counts (Columns) 1	2	3	4
1	Multi	10XX	14XX	18XX	25XX
2	Mono	100	135	175	200

TABLE 11

Analysis of Variance for Mean Finest Print Resolution

TWO FACTOR ANALYSIS OF VARIANCE

	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES
BETWEEN ROWS.	1	514.4590	514.4590
BETWEEN COLS.	3	320.5960	106.8650
INTERACTION	3	386.1940	128.7310
ERROR TERM	147	6134.4900	41.7312
TOTAL	154	7355.7400	

```
SIGNIFICANT OF ROW VARIABLE
      F=  12.33     DF=  1 , 147
      THE EXACT PROBABILITY IS .00092
      THIS IS SIGNIFICANT AT THE .01 LEVEL
SIGNIFICANCE OF COLUMN VARIABLE
      F=   2.56     DF=  3 , 147
      THE EXACT PROBABILITY IS .05609
      THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
SIGNIFICANCE OF INTERACTION
      F=   3.08     DF=  3 , 147
      THE EXACT PROBABILITY IS .02863
      THIS IS SIGNIFICANT AT THE .05 LEVEL
```

The change in resolution was found for each student by comparing copies 10 and 50 and using the net gain or loss of resolution in the ANOVA. Table 12 contains the results of the change in print resolution ANOVA.

TABLE 12

Analysis of Variance for Change in Print Resolution

TWO FACTOR ANALYSIS OF VARIANCE

	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES
BETWEEN ROWS.	1	5.6133	5.6133
BETWEEN COLS.	3	176.6690	58.8896
INTERACTION	3	293.1810	97.7271
ERROR TERM	145	8744.9900	60.3103
TOTAL	152	9220.4500	

```
SIGNIFICANT OF ROW VARIABLE
     F=    0.09     DF=   1  , 145
     THE EXACT PROBABILITY IS .75873
     THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
SIGNIFICANCE OF COLUMN VARIABLE
     F=    0.98     DF=   3  , 145
     THE EXACT PROBABILITY IS .59287
     THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
SIGNIFICANCE OF INTERACTION
     F=    1.62     DF=   3  , 145
     THE EXACT PROBABILITY IS .18574
     THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
```

Stencil edge definition was measured by visually inspecting the completed stencil with a recticuled microscope before printing and recording the number of teeth or peaks per millimeter along the edge of an image. The image used was Zone C of the test object. To allow for fabric weave the microscope was placed on the two end groups or targets and also on the center one. The average number of peaks was recorded after viewing each of the 3 areas once. This process was repeated after printing. The net change in resolution, in peaks per millimeter, was used as data for the ANOVA. Table 13 contains the results of the change in stencil edge definition ANOVA.

TABLE 13

Analysis of Variance for Change in Stencil Edge Definition

TWO FACTOR ANALYSIS OF VARIANCE

	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES
BETWEEN ROWS.	1	0.0108	0.0108
BETWEEN COLS.	3	21.3550	7.1183
INTERACTION	3	3.8199	1.2733
ERROR TERM	108	305.3270	2.8271
TOTAL	115	330.5120	

SIGNIFICANT OF ROW VARIABLE
F= 0.00 DF= 1 , 108
THE EXACT PROBABILITY IS .9495
THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
SIGNIFICANCE OF COLUMN VARIABLE
F= 2.52 DF= 3 , 108
THE EXACT PROBABILITY IS .06082
THIS IS NOT SIGNIFICANT AT THE .05 LEVEL
SIGNIFICANCE OF INTERACTION
F= 0.45 DF= 3 , 108
THE EXACT PROBABILITY IS .72155
THIS IS NOT SIGNIFICANT AT THE .05 LEVEL

Any factors which the ANOVA's showed to have a significant effect were then subjected to further testing to see exactly which levels of the factor were significantly different. A Newman-Keuls range test was used for these cases. In order to accomplish this, the mean for each level of the factor in question was needed. All of the means appear in Tables 14, 15, and 16. Row and column numbers refer to each fabric sample of the ANOVA.

TABLE 14

Treatment Means for Average Print Resolution

(Standard deviations also included in program)

MEAN AND STANDARD DEVIATIONS

ROW	1	COLUMN	1	MEAN=	22.53	STD=	6.51	N=	18
ROW	1	COLUMN	2	MEAN=	25.36	STD=	8.26	N=	21
ROW	1	COLUMN	3	MEAN=	23.69	STD=	6.18	N=	19
ROW	1	COLUMN	4	MEAN=	26.84	STD=	6.10	N=	18
ROW	1			MEAN=	24.63	STD=	6.93	N=	76
ROW	2	COLUMN	1	MEAN=	20.00	STD=	6.10	N=	20
ROW	2	COLUMN	2	MEAN=	17.52	STD=	5.91	N=	20
ROW	2	COLUMN	3	MEAN=	24.44	STD=	6.33	N=	18
ROW	2	COLUMN	4	MEAN=	21.90	STD=	5.83	N=	21
ROW	2			MEAN=	20.89	STD=	6.43	N=	79
COLUMN	1			MEAN=	21.20	STD=	6.34	N=	38
COLUMN	2			MEAN=	21.54	STD=	8.15	N=	41
COLUMN	3			MEAN=	24.06	STD=	6.18	N=	37
COLUMN	4			MEAN=	24.18	STD=	6.39	N=	39

TABLE 15

Treatment Means for Change in Print Resolution

(Standard deviations also included)

MEAN AND STANDARD DEVIATIONS

ROW 1	COLUMN 1	MEAN=	-0.67	STD=	5.41	N=	18
ROW 1	COLUMN 2	MEAN=	3.48	STD=	8.89	N=	21
ROW 1	COLUMN 3	MEAN=	-1.37	STD=	6.18	N=	19
ROW 1	COLUMN 4	MEAN=	1.67	STD=	8.71	N=	18
ROW 1		MEAN=	0.86	STD=	7.61	N=	76
ROW 2	COLUMN 1	MEAN=	2.84	STD=	12.04	N=	19
ROW 2	COLUMN 2	MEAN=	-0.75	STD=	6.23	N=	20
ROW 2	COLUMN 3	MEAN=	-1.17	STD=	7.03	N=	18
ROW 2	COLUMN 4	MEAN=	0.65	STD=	5.13	N=	20
ROW 2		MEAN=	0.40	STD=	8.01	N=	77
	COLUMN 1	MEAN=	1.14	STD=	9.46	N=	37
	COLUMN 2	MEAN=	1.41	STD=	7.91	N=	41
	COLUMN 3	MEAN=	-1.27	STD=	6.52	N=	37
	COLUMN 4	MEAN=	1.13	STD=	6.98	N=	38

TABLE 16

Treatment Means for Change in Stencil Edge Definition

(Standard deviations also included)

MEAN AND STANDARD DEVIATIONS

ROW 1	COLUMN 1	MEAN=	1.17	STD=	1.20	N=	18
ROW 1	COLUMN 2	MEAN=	2.00	STD=	1.85	N=	15
ROW 1	COLUMN 3	MEAN=	2.19	STD=	1.91	N=	16
ROW 1	COLUMN 4	MEAN=	2.53	STD=	2.03	N=	17
ROW 1		MEAN=	1.95	STD=	1.80	N=	66
ROW 2	COLUMN 1	MEAN=	1.40	STD=	1.35	N=	10
ROW 2	COLUMN 2	MEAN=	1.82	STD=	1.33	N=	11
ROW 2	COLUMN 3	MEAN=	2.59	STD=	1.42	N=	17
ROW 2	COLUMN 4	MEAN=	2.00	STD=	2.04	N=	12
ROW 2		MEAN=	2.04	STD=	1.58	N=	50
	COLUMN 1	MEAN=	1.25	STD=	1.24	N=	28
	COLUMN 2	MEAN=	1.92	STD=	1.62	N=	26
	COLUMN 3	MEAN=	2.39	STD=	1.66	N=	33
	COLUMN 4	MEAN=	2.31	STD=	2.02	N=	29

The only factor which showed important significance was the interaction of mesh count and fabric type for mean print resolution. With interaction taking place, each and every combination of the two were tested to find out which specific combinations gave the best results. The means from Table 14 were used and arranged in order from lowest to highest in Table 17.

TABLE 17

Newman-Kuels Range Test for Average Print Resolution

Arrangement of Means

	1	2	3	4	5	6	7	8
$\overline{Y}$ =	17.52	20.00	21.90	22.53	23.69	24.44	25.36	26.84
N =	20	20	21	18	19	18	21	18
$\frac{1}{N}$ =	.05	.05	.048	.055	.053	.055	.048	.055

$\overline{Y}$= Mean resolution for each fabric tested (from Table 14).

N= Number of students in each fabric group.

TABLE 18

Newman-Kuels Range Test Comparisons Tested

Error Mean Squared = 41.73   Degrees of Freedom = 147

Compute $S_{\bar{Y}}$ for each comparison

$S_{\bar{Y}}$ = EMS 1/2 $(1/n_i + 1/n_j)$

	Comparison	Range	Standard Error ($S_{\bar{Y}}$)	X	Range Value	=	Adjusted Test Range		Comparison j -Comparison i	
a)	1 & 2	2	1.44		2.80		4.03	$>$	2.48	
b)	1 & 3	3	1.43		3.36		4.80	$>$	4.38	
c)	1 & 4	4	1.48		3.69		5.46	$>$	5.01	
d)	1 & 5	5	1.47		3.92		5.76	$<$	6.17	*
e)	1 & 6	6	1.48		4.10		6.06	$<$	6.92	*
f)	1 & 7	7	1.43		4.24		6.06	$<$	7.84	*
g)	1 & 8	8	1.48		4.36		6.45	$<$	9.32	*
h)	2 & 3	2	1.43		2.80		4.00	$>$	1.90	
i)	2 & 4	3	1.48		3.36		4.97	$>$	2.53	
j)	2 & 5	4	1.47		3.69		5.42	$>$	3.69	
k)	2 & 6	5	1.48		3.92		5.80	$>$	4.44	
l)	2 & 7	6	1.43		4.10		5.86	$>$	5.36	
m)	2 & 8	7	1.48		4.24		6.27	$<$	6.84	*
n)	3 & 4	2	1.46		2.80		4.08	$>$	0.63	
o)	3 & 5	3	1.45		3.36		4.87	$>$	1.79	
p)	3 & 6	4	1.46		3.69		5.39	$>$	2.54	
q)	3 & 7	5	1.42		3.92		5.57	$>$	3.46	
r)	3 & 8	6	1.46		4.10		5.99	$>$	4.94	

* = Significant at .05 level

TABLE 18 (Continued)

Comparison	Range	Standard Error ($s_{\bar{Y}}$) X	Range Value =	Adjusted Test Range		Comparison j -Comparison i
s) 4 & 5	2	1.50	2.80	4.20	>	1.16
t) 4 & 6	3	1.51	3.36	5.07	>	1.91
u) 4 & 7	4	1.47	3.69	5.46	>	2.83
v) 4 & 8	5	1.51	3.92	5.92	>	4.31
w) 5 & 6	2	1.50	2.80	4.20	>	0.75
x) 5 & 7	3	1.45	3.36	4.87	>	1.61
y) 5 & 8	4	1.50	3.69	5.53	>	3.15
z) 6 & 7	2	1.47	2.80	4.12	>	0.09
aa) 6 & 8	3	1.51	3.36	5.07	>	2.40
bb) 7 & 8	2	1.47	2.80	4.12	>	1.48

* = Significant at .05 level

The error mean squared (EMS) and its degrees of freedom were found in Table 11 and the EMS was used to obtain the standard error of the means for each comparison in Table 18. When multiplied by a table value for each range, an adjusted figure was obtained which was compared to the difference between the two means being tested. If the difference was greater than the adjusted range, the two comparisons were significantly different. A .05 level of significance was used for all comparisons. Those comparisons which could not be found significantly different were underlined together in Table 19.

TABLE 19

Results of Newman-Kuels Range Test

1	2	3	4	5	6	7	8
17.52	20.00	21.90	22.53	23.69	24.44	25.36	26.84
(135	100	200	10XX	18XX	175	14XX	25XX)

With each fabric, the incidence of stencil adhesion failures, leaks and plugging problems for ink flow were analyzed to make inferences about student's chances for successful results. This information was reported by students on the student project report form (Appendix C). The frequency of the above three problems were tallied separately and put in histogram form. The percentage of students in each section reporting a problem was also calculated and appears with each graph below.

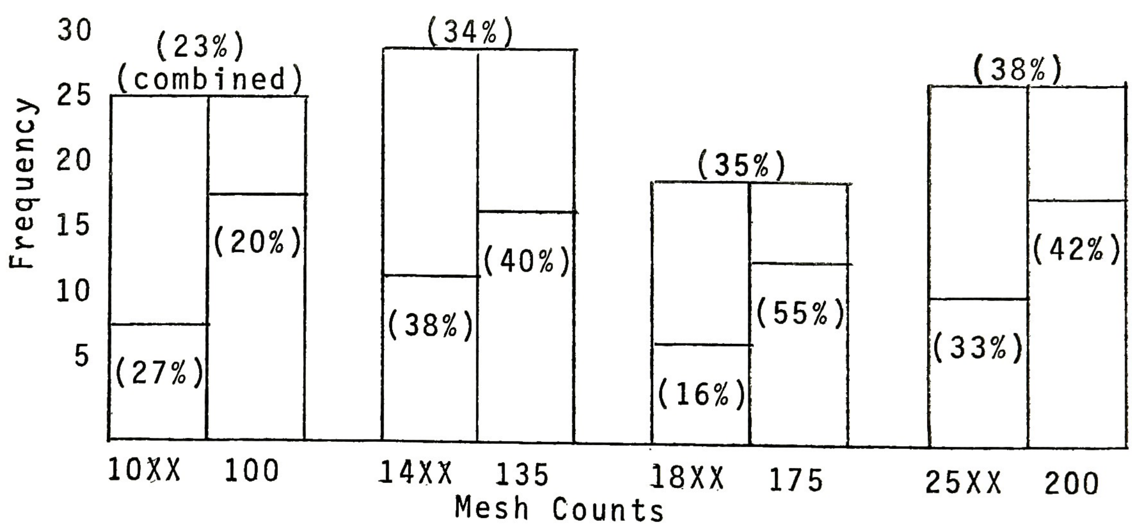


FIGURE 6

Incidence of Leaks in Stencil During Printing for all Mesh Counts

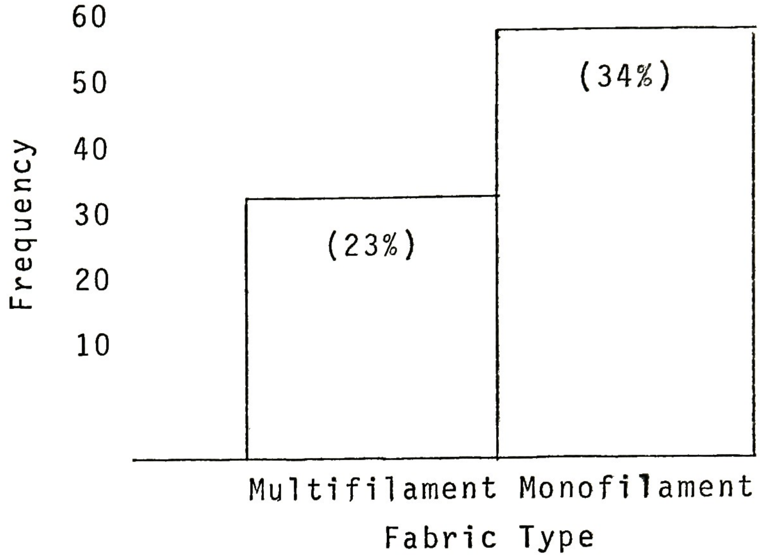


FIGURE 7

Incidence of Leaks in Stencil During Printing for Fabric Type

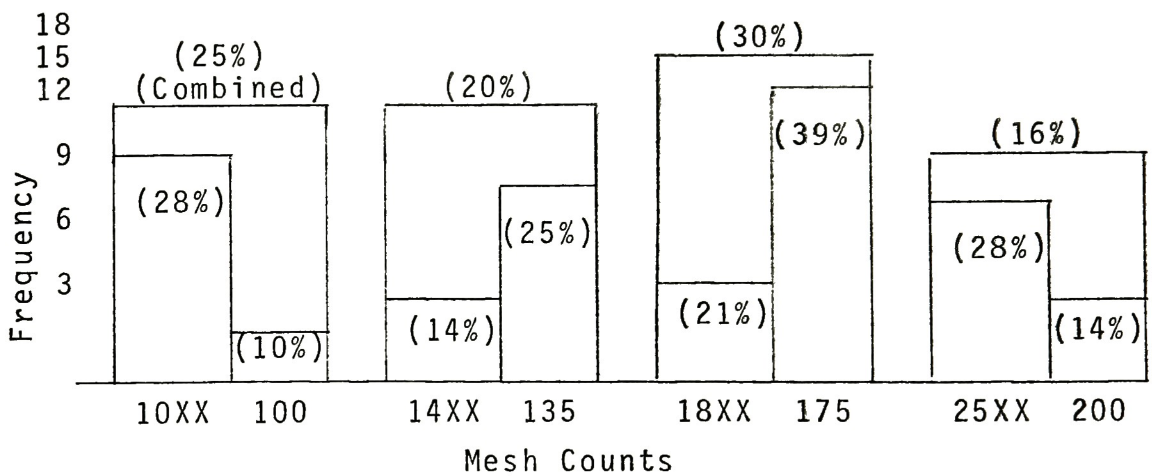


FIGURE 8

Incidence of Stencil Adhesion Failures for all Mesh Counts

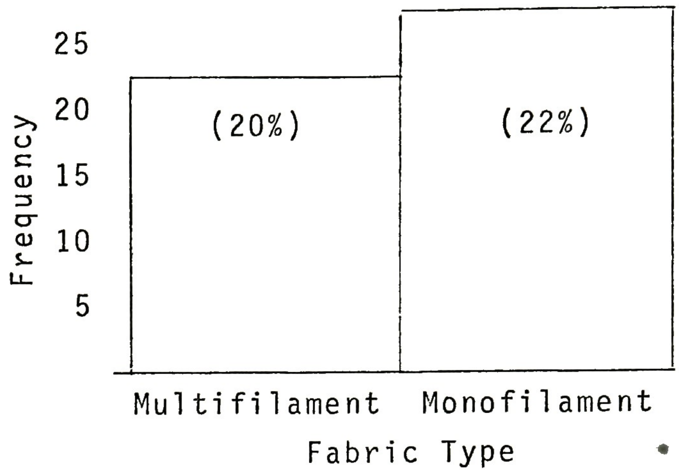


FIGURE 9

Incidence of Stencil Adhesion Failures
for Fabric Type

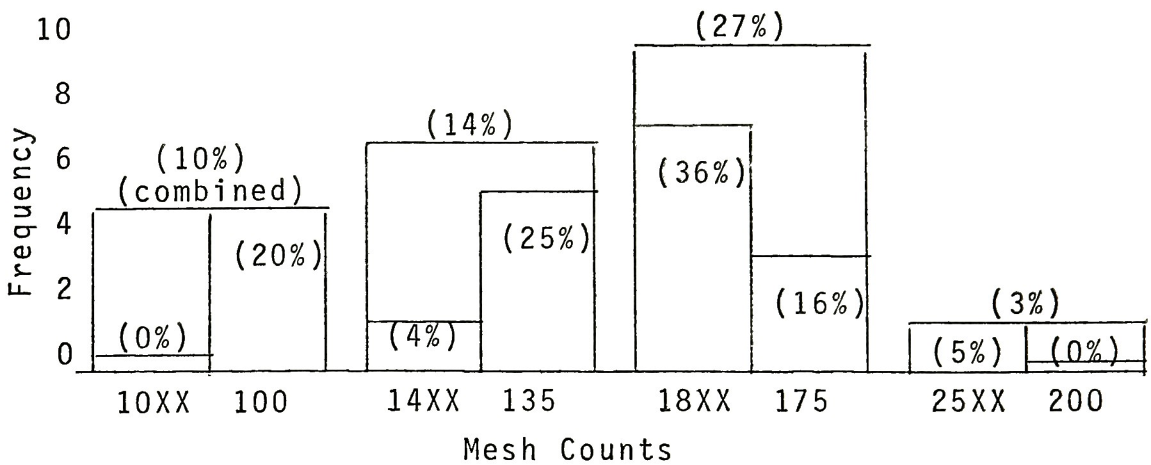


FIGURE 10

Incidence of Plugging Problems in Mesh
During Printing for all Mesh Counts

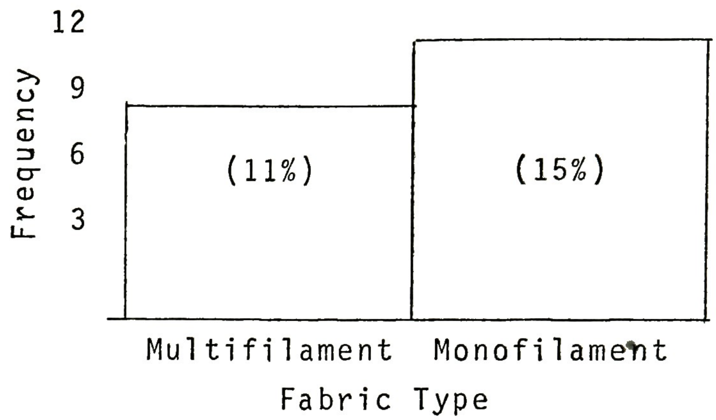


FIGURE 11

Incidence of Plugging in Mesh
During Printing for Fabric Type

DISCUSSION OF THE RESULTS

The most important of the results concerning print quality (edge definition, mean resolution and change in resolution) was the fact that the different fabrics only had an effect on the mean resolution. Further, because of interaction, it can't be shown from the results that any predictable trend is present. Although the factor of mesh number fell just short of being significant, and the higher mesh numbers did produce slightly finer resolution as shown by the means in Table 14, the ANOVA still failed to show significance at the .05 level. Even if there was significance in the levels of mesh, it would not be very accurate to generalize about which fabric mesh counts are best, since interaction demands that the type of fabric will work in combination with the mesh. Both factors must be considered. In order to do that, the Newman-Kuels range test was run with the mean print resolution for each of the eight fabric type - mesh count combinations. As the results stated, the 135 mesh monofilament had significantly less resolving ability than four of the other fabrics listed. Closest to the 135 mesh was the 100 mesh monofilament. These two are among the lowest of the mesh counts used and will give the lowest resolution. After eliminating those two meshes, the choice for finer resolving fabrics is up to the individual since the rest cannot be shown to be significantly different from each other. Although statistically they aren't different, it would still be wise to check the mean resolution of each before making a choice as to which fabric would be useable for a particular job or fabric inventory.

Generally speaking, the multifilament fabrics gave better results when it came to student success in printing as measured by stencil adhesion failures and leakage during printing (Figures 6-9). This seems very appropriate, because of the configuration of the two fabric types. The monofilament, being made up of only one smooth strand for each thread, has much less surface area for a stencil to adhere to than the many strands of a multifilament thread. To help overcome this, the monofilament fabrics are roughened with 500 mesh silicone carbide. This is a manual process, however, and if not done thoroughly, will still have many smooth threads that an indirect stencil will have trouble adhering to. Thus the chances are increased for more breakdown, leaks and adhesion failures throughout the process. The leakage problems in the experiment were very consistent throughout all levels of mesh counts. The monofilament always had more leaks than the multifilament. Correspondingly, the total number of stencil adhesion failures was also higher for the monofilament, but the number of failures across the levels of the different mesh counts took a big drop at the highest mesh group. It seemed like a trend was beginning where the number of adhesion failures would increase with mesh count, but the highest count produced the least number of failures.

This same occurrence took place when ink flow characteristics were inspected by checking the number of people reporting plugging problems during printing. Again, the monofilament seemed to give more trouble, which is opposite of what one would expect because of the smooth threads. The incidence of plugging was on the increase as the mesh grew finer, but just like stencil adhesion, the trouble all but vanished when the highest group of meshes was checked. It could be suspected that a lack in the accuracy of reporting these problems may be a reason for the inconsistency. One way to check the consistency of ink flow reporting throughout the meshes is to do a correlation test. It would seem logical that the meshes which produced the highest resolutions throughout the run would have to be relatively free from plugging problems if the resolution was to remain consistently high. So to see if this correlation was really taking place, a simple test called a corner test[12] was used for the data in Table 20. A plot of the corner test appears in Appendix E. The corner test showed no correlation of the data at the .05 level, so it could be assumed that the reporting of this particular information by some students

TABLE 20

Data For Corner Test

No. of plugging problems reported	5	4	0	0
Mean resolution achieved	17.52	20	21.9	22.53
No. of plugging problems reported	7	3	1	1
Mean resolution achieved	23.69	24.44	25.36	26.84

was not as complete as it should have been. Data for ink flow were obtained from the back of the student report form where persons wrote in individual comments. If plugging happened to be mentioned, these incidents were entered as data. Perhaps a specific blank on the student report sheet should have been present, asking for the number of times the screen had to be cleaned because ink dried between the threads of the mesh.

Finally, many of the results presented from the different analyses appear very different from what a person might expect to happen, especially in industry, with the different meshes or fabric types. Some results show no patterns whatsoever. Again, the special situation of variability in a school laboratory can be cited to explain these effects. The most important variable is the student. Although everyone is given the exact same set of directions, has the same materials, and sees the same demonstrations, they are all doing these processes manually. This allows for a big difference in the way that the people judge things like pressures and amounts when they are doing things for the first time, such as stretching or degreasing the screen printing fabric. What the data show then is that in many cases, since there is so much variation present between students, it really makes no difference what levels are used. All will give similar results in an educational setting.

FOOTNOTES FOR CHAPTER 8

12. Rickmers & Todd, Statistics, An Introduction (New York, McGraw-Hill Inc., 1967), p. 403.

SUMMARY AND CONCLUSIONS

The choice of a specific fabric or range of fabrics for a school to use is not a clear-cut decision since some of the different fabrics tested performed better than others in certain areas and vice versa. Another reason that a simple generalization cannot be made is because of the interaction that took place between the fabric type and mesh count in the area of print resolution. Yet another is the variation from student to student.

Bearing with these limitations, the criteria which will be used here for a recommended fabric in the realms of print quality and student success are mean print resolution, leakage problems and stencil adhesion problems. As far as the rest of the criteria tested, the study showed there was no effect of the different fabrics or stencil edge definition or change in print resolution. The data for ink flow and plugging problems proved to be inconclusive, so no use of this factor will be made when giving recommendations.

Based on the data, when choosing a fabric for quality of printing, or fine resolution, there are several choices. Many of the meshes were shown not to be significantly different in the Newman-Kuels comparison, so any of the similar ones could be used with equal results. If one "best performance" award had to be given, the 25XX multifilament will provide the finest resolution, more than 26 lines per cm. The best fabric in the monofilament type for resolution is the 175 mesh. It provides the resolution that was not found to be different from the 25XX. On the other hand, if such fine resolution is not needed, such as for applying coatings, the fabrics on the lower end of the resolution scale also happen to be of coarser meshes. These are generally less expensive and give a thicker layer of ink when compared to those finer weaves just mentioned. The specific meshes could be 135 in the monofilament or 10XX for multifilament fabric. Though the ANOVA showed mesh count as not being a significant factor in mean print resolution, an informal glance at the table for the resolution means (Table 14) could further support a decision. It shows that the 10XX and 135 mesh fall into mesh columns 1 and 2 where the means are nearly equal and are less than the other two columns. The 175 and 25XX mesh fall nicely into columns 3 and 4 with the larger mean resolutions.

When considering student success as a major factor for fabric choice, the best results with leaks and stencil adhesion were definitely made with the multifilament fabrics. All mesh counts showed similar results, but care should be taken when getting into higher mesh counts. The plugging and ink flow data were inconclusive, but if the trend toward more plugging at higher meshes was accurate, more problems could be gained from blocked images on the screens than are worth the capabilities of finer resolution.

RECOMMENDATIONS FOR FURTHER STUDY

Since results in this area proved to be inconclusive, continued investigation of plugging problems with the different mesh counts is needed. A study could be run, without even using a test object, and all emphasis could be put on accurately observing the ink plugging problems of the students. It could define the criteria for identifying the problem, perhaps such as the necessity of cleaning the screen during printing, provide a means for recording the number of problems, like a report sheet with a specific blank for a numerical value, and finally, it would plot and evaluate the results.

Another area where further research would be worthwhile could be to test different fabric materials such as nylon vs polyester. The same criteria could be used for evaluation or different effects might be sought.

The meshes used in this study only reached a maximum mesh count of 200 openings per linear inch. Monofilament fabrics can reach mesh counts of 500 openings per inch. A similar study using the fine monofilament mesh counts may prove interesting or more conclusive.

One of the many objectives in a lab activity such as screen printing is to bring about an improvement or mastery of a manual skill. Another possibility for investigation could be to look at the difference between pre and post-assignment skills for each treatment level. It is important to remember though, that all of the students in a class may be starting at different ability levels. Some may have had experience in working with their hands and may be skilled in psychomotor types of activities. For others, the kinds of routines may be brand new. In a post-high school graphic arts course, some students may even have performed the same process numerous times in a previous class. A possibility for further investigation may be present in attempting to see which fabrics will bring about the greatest improvement of students work as they gain some experience in using the process. A two or three color printing exercise could be assigned, and an analysis of covariance used to allow for the differing skill levels of the students at the start of the test.

BIBLIOGRAPHY

BIBLIOGRAPHY

Advance Process Supply Corp., "It's a Screen Printed World," Chicago, Advance Process Supply Corp., 1969, Film.

Bedirian, George, A Study of the Effect On Direct Stencil Edge Definition of Emulsion Thickness, Screen Mesh Count, Fabric Thread Thickness and Coater Blade Thickness, Rochester Institute of Technology, May, 1977, Unpublished thesis.

Bresadola, Thomas R., An Experiment on the Effects of Humidity on Screen-Process Stencils, South Dakota State University, 1970, Unpublished thesis.

Fuller, Lynn, Screen Printing Considerations for Thick Film Microelectronics, Rochester, NY, Rochester Institute of Technology, June, 1973, Unpublished thesis.

Kyle, E.J., "Toward the One-Mil Line," Screen Printing (November, 1970 to June 1971).

Kyle, E.J., "Split Personality," Screen Printing (June, 1977), 50.

Majestic Bolting Cloth Corp., "About Fabrics," Technical publication, New York, Majestic Bolting Cloth Corp., No date.

Rickmers & Todd, Statistics, An Introduction (New York, McGraw-Hill Inc., 1967), p. 403.

Shaw, John S., "Screen Printing . . . Today and Tomorrow," Graphic Arts Monthly, (October, 1973), 88-89.

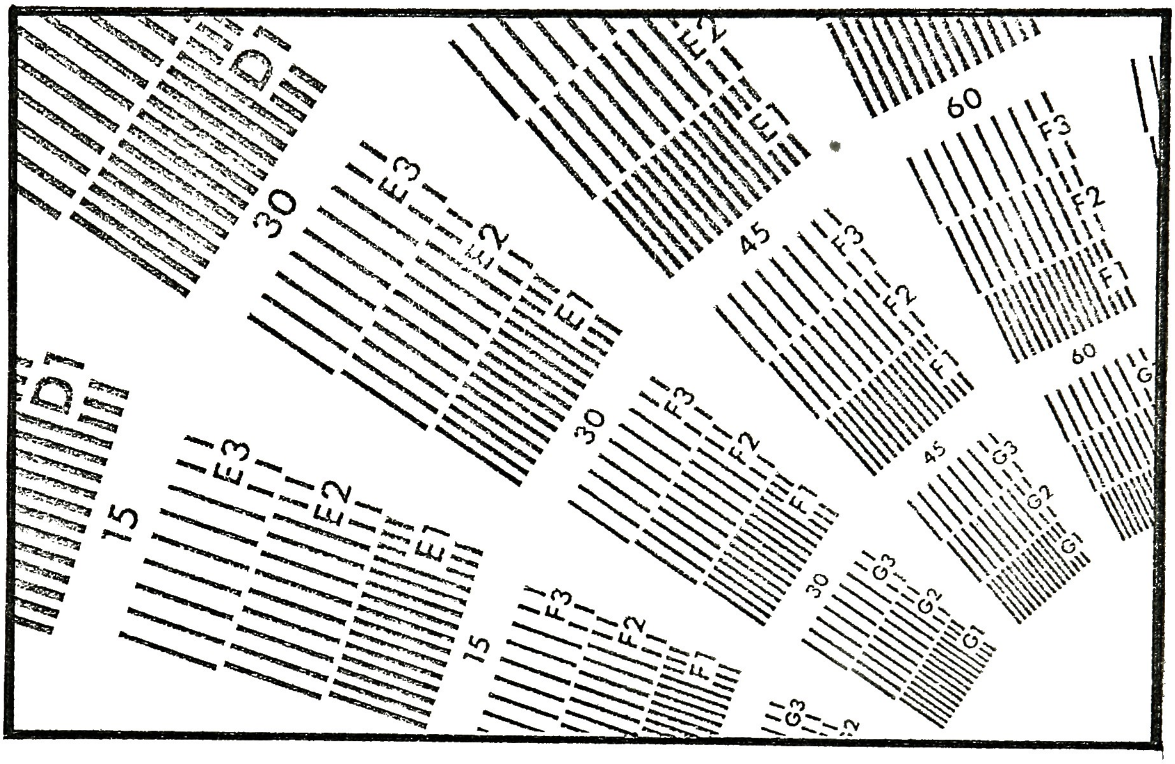
Tenorio, James K., Unpublished notes, Department of Graphic Communications, University of Wisconsin-Stout, Menomonie, Wisconsin, 1976.

Zurich Bolting Cloth Mfg. Ltd., Manual for the Use of NITEX Monofilament Screen Fabrics for the Graphic Arts Industry, Zurich, The Zurich Bolting Cloth Mfg. Co. Ltd., No date.

APPENDIX A:

E.J. Kyle's Resolution Test Object

APPENDIX A



A portion of E.J. Kyle's test object

APPENDIX B:

Instruction Sheets Given to Subjects

APPENDIX B

NAME________________________________

University of Wisconsin-Stout
Graphic Communications Department
Instructor: Tenorio

SECTION______ LOCKER #____________

SCREEN PRINTING ASSIGNMENT

Objectives

Upon completion of this laboratory assignment, the student will achieve these objectives from those listed in the course description.

Category	Objective
Design and Layout	B
Copy Preparation	B
	D
	H
Photo Conversion	A
	B
Image Carriers	I
Image Transfer	D
Production Management	B

Information

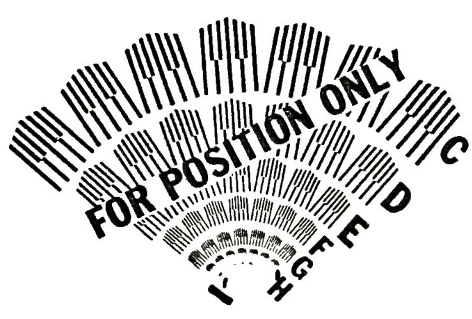
In this assignment you will be screen printing the cover of your class notebook. In addition to making covers, this assignment will be used as a simple quality control check for our materials in the lab. Through this check, you will get to see and try some of the tools used by the graphic arts industry for measurement of materials and printing quality.

Only certain sections of 130-140 will be involved in this controlled exercise, so be sure to follow directions given in your class. Some instructions will be completely opposite of those for other sections. Be sure to tell the lab assistant that you are in one of the "experimental" sections when asking for help so they will be better able to assist you.

Procedure for Assignment

1. Design and layout a 2-color notebook cover to be screen printed. Your design must include the following copy: Graphic Arts; U.W.-Stout; and your name. Each color must also include the resolution test object (which measures 7.5 x 4.5cm) supplied by your instructor. Be sure it is included on your layouts. The maximum image area is 6" x 9".

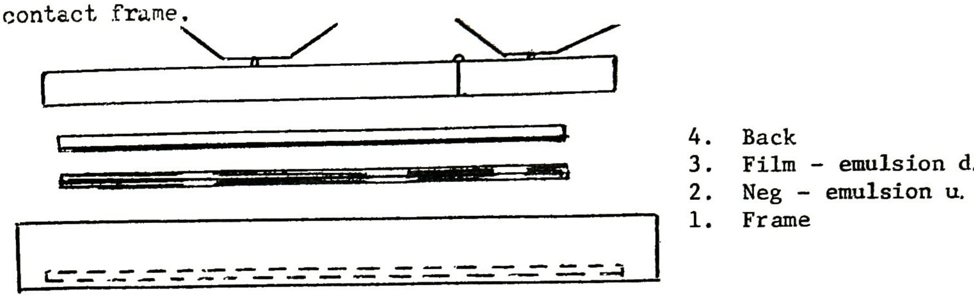
Use this picture of the test object for sizing and positioning on your layouts. Instructor will provide film positive for actual use.



2. Prepare a paste-up of the type matter and make a film negative.

3. With a second sheet of Ortho film, a contact frame and the point light source, make a film positive. Load the contact frame as shown:

Loading the contact frame.



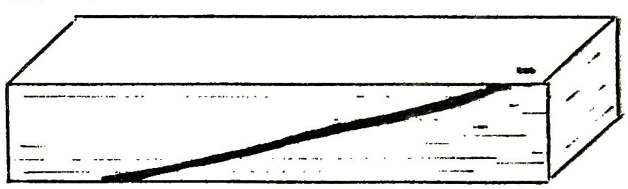
4. Obtain a piece of screen printing fabric from your instructor; be sure to note the number on it. Stretch the fabric tightly onto the frame while wet.

5. Prepare the fabric by washing it with degreaser and rinsing with water. This is necessary for both new and used screens to remove sizing, grease and solvents. After cleaning the screen, it may have to be re-stretched if you were careless or too rough with it. Monofillament fabrics (orange in our lab) will have to be roughened before degreasing.

6. Immediately after cleaning, expose, process and adhere the Blue Poly 2 photographic stencil to the fabric. Follow exact directions given in class.

7. Mask the surrounding open mesh with tape and liquid blockout.

8. Obtain 50 sheets of index stock and three cover sheets from your instructor. Number the white sheets 1-50 in the upper right-hand corner and draw a diagonal line across the side of the stack to help keep the sheets in order. Do not number the cover sheets.



9. Print 2 cover sheets and 50 copies in order, keeping track of the pinholing and plugging problems asked about in the report sheet. Collect the sheets as soon as they are dry so they won't get lost.

10. Clean ink from the fabric with ink solvent but DO NOT remove the stencil. Leave the stencil and fabric on the frame and turn it in to the lab assistant or your instructor. Obtain cleanup signature for the remaining materials.

11. Complete the project report sheet for the first color.

12. Get a second frame and new piece of fabric from your instructor. Prepare the frame and stencil for the second color/side of the cover

13. Print the second color being sure to follow the sheet numbering again so they are printed in the same order as the first color.

14. Clean the ink from the fabric as in step 10.
    NOTE: Failure to obtain valid signature for turning in the stencil and fabric on the frame and for cleanup will result in the loss of 3 points for each color.

15. Complete the project report sheet for the second color.

Submit Assignment for Evaluation

Place the following materials in the order listed and insert them together in a plastic folder. Your name and drawer number should appear on the evaluation sheet.

1. The evaluation sheet on top.
2. The project report sheet.
3. Layouts: Thumbnail, Rough, Comprehensive.
4. Paste-up (type matter only).
5. Film negative and positive for type matter.
6. Put the 50 printed copies in a black film bag and attach the plastic folder to it. Save the three cover sheets for the notebook binding assignment later in the course.

Supplies

1. Two sheets of 8" x 10" Kodalith Ortho film - Communications Storeroom.
2. Two 8" x 10" pieces of Blue Poly 2 photographic stencil film - Communications Storeroom.
3. One 10" x 12" film positive of resolution test object - Instructor.
4. 50 sheets stock and 3 cover papers - Instructor.
5. Screen printing fabric and frame - Instructor.

References

1. Graphic Communications, Broekhuizen, pps. 41-53, 182-190, 195-198, 212-219.
2. Silk Screen Printing, Eisenberg, James and Kafka, Francis J.
3. Silk Screen Process Methods of Reproduction, Zahn, Bert.
4. It's a Screen Printed World, Film F659.
5. Silk Screen Printing, Film F13.
6. Silk Screen Fundamentals, Film F640.
7. Basic Methods of Screen Process Printing, Film F 729.
8. Screen Printing (Screen Printing using hand-cut paper stencil, photo stencil & film cut stencil) slide-tape Z122.G7 Prog. 35 Part I & II.
9. Screen Printing Multi Colors in Cloth, Slide-tape Z122.G7 Prog. 39.
10. Silk Makers of Japan, Film F640.
11. Vera Paints IBIZA in the Sun, Film F857.

Study Questions

These questions will assist you in studying the material pertinent to this assignment. The answers can be found in the textbook and reference books. Several of the questions can be answered from material presented in the lecture sessions.

1. List four ways of preparing screen printing stencils.

2. What are two advantages of screen printing reproduction methods over the other major printing processes?

3. Describe the image transfer principle involved with screen printing.

4. Name two materials other than silk that can be used for the screen material.

5. Name several commercial objects or materials that are screen printed.

6. How fine of resolution did you achieve (whole target zone printed)?

Zone	Lines/cm	Line Thickness (mm)
C	7	.70
D	10	.50
E	14	.36
F	20	.25
G	28	.18
H	40	.12
I	56	.09

Name ____________________ Date Submitted __________ Drawer Number _____

Section _____

EVALUATION FOR SCREEN PRINTING
"QC Section"

Criteria	Points Possible	Points Earned Student	Points Earned Instructor
Design and Layout			
Thumbnail sketches submitted	1		
Rough layout submitted	1		
Comprehensive layout submitted	1		
Resolution test object included for each color	1		
Copy Preparation			
Photo composer used or neatly lettered	1		
Name included	1		
Final paste-up submitted	1		
clean	1		
free from physical damage	1		
free from typographical errors	1		
correct alignment	1		
black and white	1		
Photo Conversion			
Film negative developed to solid step 4	1		
Film positive developed to adequate density	1		
Screen & Stencils			
Stencils agree 100% with paste-up	1		
image areas (type) completely open	1		
good adhesion to screen	1		
liquid blackout used in masking non-image areas	1		
leaks in non-image areas blocked out	1		
Image Transfer - Type Matter Only			
50 copies submitted	1		
Copies printed in numbered order	1		
Color register agrees with layout	1		
Image not smeared	1		
Solid ink coverage in image areas	1		
Non-image areas free of ink	1		
Project report sheet completed	1		
Screen cleaned after first color	3		
Screen cleaned after second color	3		
Total Points	32		
Late assignment penalty			
Total			

NOTE!! The screen printing frames must be cleaned before this assignment is turned in for evaluation. You must have the instructor's or the lab supervisor's approval.

First color ______________________________
lab instructor's approval signature

Second color ______________________________
lab instructor's approval signature

APPENDIX C:

Student Report Form

APPENDIX C

Student Report Form

Name ____________________ Section ___________ Date __________

1. What color ink did you use for first color:_________ second:_________?

2. What was the mesh count of the fabric? (put a "1" for first color, "2" for second color)

   Multifilament ___10XX   Monofilament ___100 mesh   ___230 mesh

   ___14XX   ___135 mesh

   ___18XX   ___175 mesh

   ___25XX   ___200 mesh

3. How many tries did it take before the stencil adhered to the fabric for

   first color? ____   second color?____

4. How many times did the stencil peel off of the fabric when you tried to remove the stencil backing for the

   first color?____   second color?___

5. Did you have any problems with the stencil breaking down and letting ink through in the non-image areas during printing for the

   first color? ___yes ___no how many leaks?_____

   second color?___yes ___no how many leaks?_____

   -if yes, where did the breakdown occur for the

   first color? ___around letters or images ___in non-image areas

   second color? ___around letters or images ___in non-image areas

   -if yes, how large were the leaks from the stencil breakdowns (could be measured on the print) for the (indicate how many)

   first color?___tiny (pinhole size)   second color?___tiny

   ___small(up to $1mm^2$)   ___small

   ___medium(up to $2mm^2$)   ___medium

   ___large(more than $2mm^2$)   ___large

6. How many times did you have to remake the stencil after you started printing because the stencil failed to hold for the

   first color?____   second color?____

7. Please explain any problems or difficulties you may have encountered on the back of this sheet. Also mention the things that went well for you.

DO NOT WRITE IN THIS SPACE

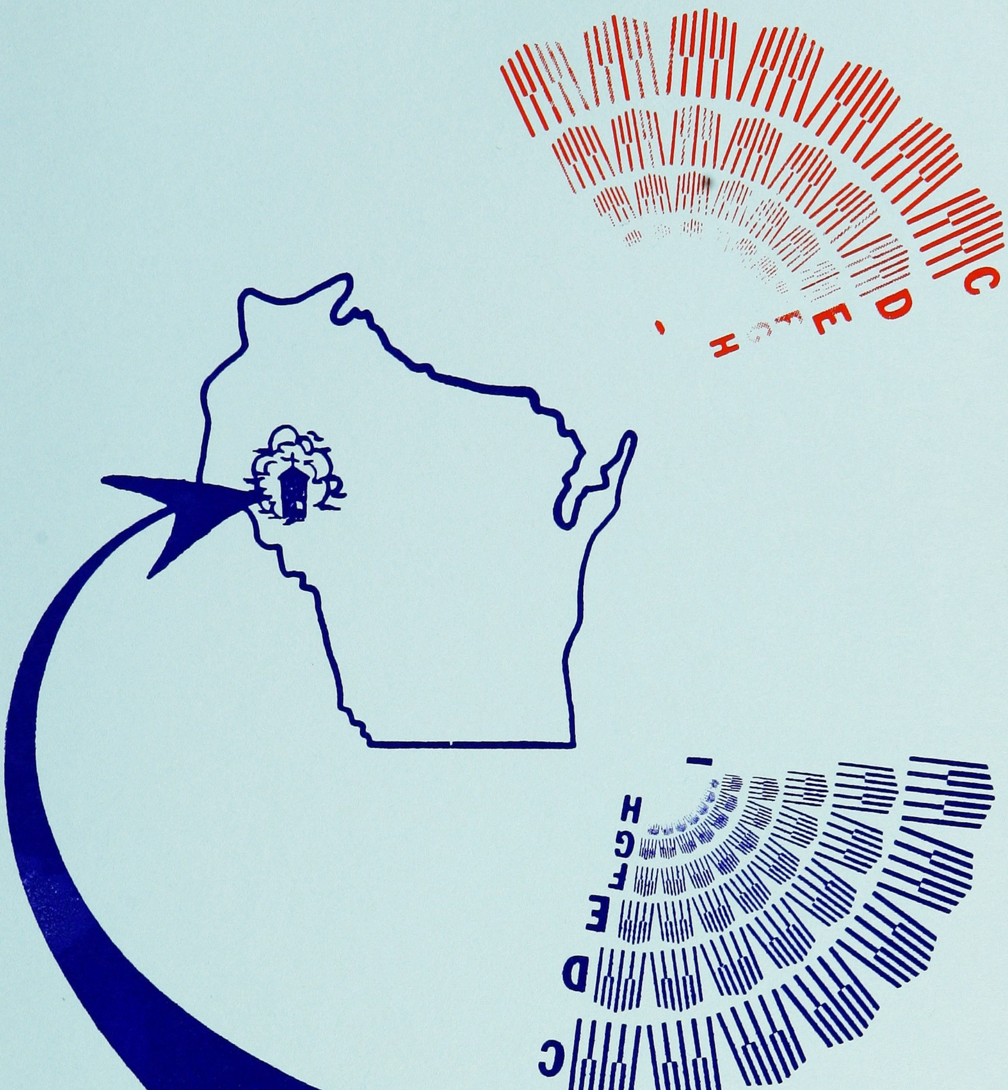
R	10	20	30	40	50	$\bar{R}$	$\Delta\bar{R}$	10-50	$\Delta\bar{R}$
1st							1st	-	
2nd							2nd	-	

APPENDIX D:

Samples of Student Work

GRAPHIC ARTS

GRAPHIC ARTS



U.W. STOUT

graphic arts

uw stout

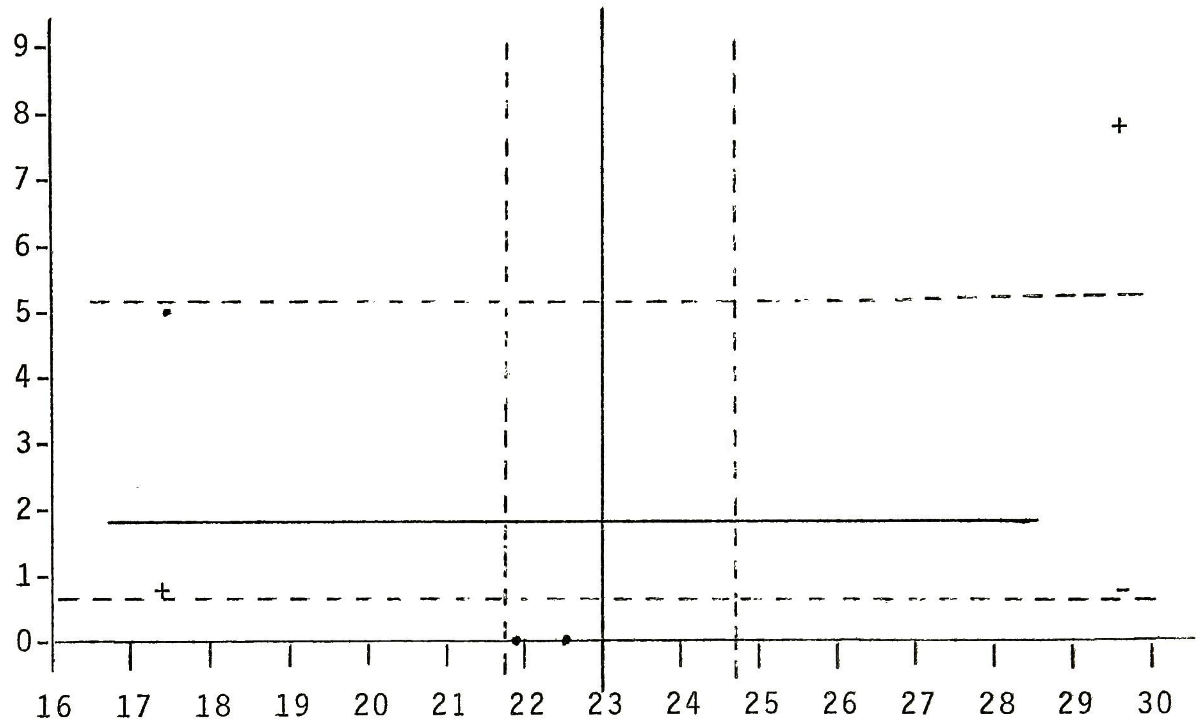
APPENDIX E:

Plot for Corner Test

APPENDIX E

Plot for Corner Test

Data from Table 20



+1-2+2-2=-1

Significance Level	Quadrant Sum
.01	15
.02	13
.05	11
.10	9